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17. Какого цвета Луна? Определяем с помощью Фотошопа.

12-15 minutes

Looking at the moon at night, when it is especially bright, few people realize that the soil of the moon is actually very dark, especially in the lunar seas, and besides, it is brown. Almost like dark chocolate.

Experts wrote about the dark brown color of the lunar soil back in the 50-60s of the twentieth century, but for most people the surface of the moon seemed light gray, approximately the same as in color photographs of NASA, taken during the so-called astronaut landing. In almost all photographs of the Apollo lunar missions of the United States (1969-1972), the color of the moon is gray as ash.

This is the color that the American images of the Apollo missions showed the Moon.

But the Chinese lunar rover, which worked on the Moon in December 2013, sent photographs of the brown Moon / C to Earth at close range, we see that the lunar sand (regolith) is brownish brown.

Such an image was sent from the Moon in 2013 by the Chinese lunar rover "Jade Hare"

So what color is the surface of the moon? Gray or brown? And if it is actually brown, then are the photographs of the landing of US astronauts on the surface of our satellite unreliable? Black and White Moon or Colored?

To understand this issue, we acted simply. First, we selected an “object” of the same **brightness** as the lunar regolith. Since astronomy knows the average reflection coefficient of the lunar soil, albedo 7-8%, then using a standard gray scale (where the gray field reflects 18%) and a professional brightness meter (Asahi Pentax), used by cameramen to determine the exposure, made a selection of textures. Used for this garden soil. But since the wet earth turned out to be darker than the required 7-8%, it had to be mixed with a small amount of cement. And this is what happened - the lunar regolith is darker than the river sand, but lighter than the garden soil.

Comparison of the lightness of the three textures.

And in order to accurately determine exactly the **color of the** lunar regolith, and not only its lightness (brightness), we used the X-Rite dtp-41 spectrophotometer available at our department of the camera

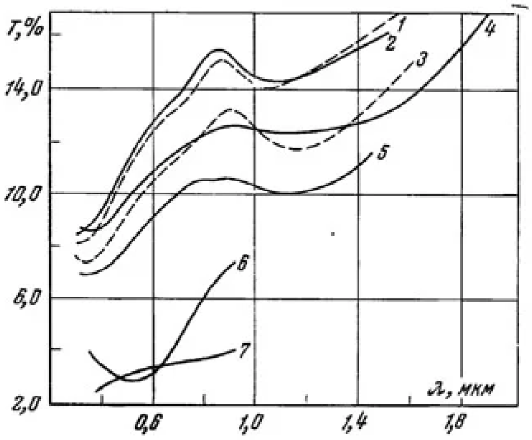
department of the All-Russian State Institute of Cinematography (Institute of Cinematography). It is the spectral reflection curve that is **unambiguous and objective.**characterization of color, while other methods, for example, visual-descriptive, are subjective. Even a photograph may not reproduce colors exactly the way the eye sees it. Depending on the settings of the camera (color profile), you may experience faded or more saturated colors. So, in our opinion, the images of the Chinese lunar rover convey the color of the regolith with excessive saturation. At the end of this article, we will show what the actual color of the lunar surface was at the landing site of the Chinese lunar rover.

Spectrophotometer X-Rite dtp-41.

So, with the help of an electronic spectrophotometer, we have selected the material that most closely repeats the graphs of the spectral reflection of the lunar regolith, taken from the book "Lunar soil from the Sea of Abundance".

наблюдается широкая полоса поглощения, которая отождествляется с $d - d$ переходом в ионе Fe^{2+}, входящем в кристаллическую решетку минералов-компонентов реголита. По данным химического анализа, содержание железа в образце, доставленном «Луной-16» равно 13,1% [1].

Наиболее низкой отражательной способностью обладает реголит из Моря Спокойствия (спектры *3* и *5*, рис. 1), а наибольшей — реголит из Океана Бурь (спектры *1* и *2*, рис. 1). Разница в спектрах образцов, отобранных с различных глубин, но из одной и той же буровой колонки, во всех случаях невелика, она не превышает 2% во всем исследованном интервале длин волн. Тем не менее отражательная способность реголита явно увеличивается по направлению от поверхности к глубине



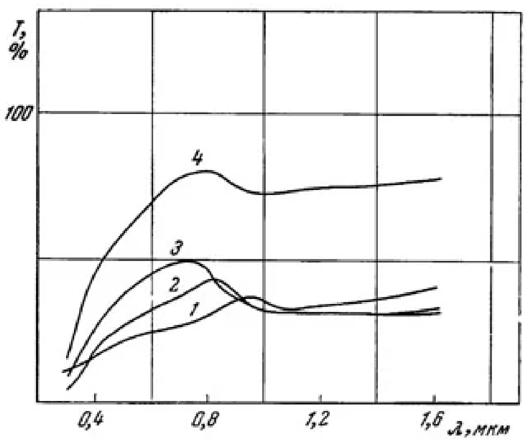


Рис. 1. Спектры диффузного отражения реголита из различных районов Луны

1 — обр. 12028,229; *2* — обр. 12028,233; *3* — обр. 10005,35; *4* — обр. Л-16-А; *5* — обр. 10005,34-5; *6* — спектр зеркального отражения обр. Л-16-А; угол падения света 60°; коэффициент отражения в произвольных единицах; *7* — приведенный спектр диффузного отражения обр. Л-16-А; коэффициент отражения при 0,5 *мкм* равен коэффициенту зеркального отражения

Рис. 2. Спектры диффузного отражения шлифов лунных горных пород

1 — брекчия, обр. 10048,53; *2* — крупнозернистый базальт, обр. 10047,25; *3* — мелкозернистый базальт, обр. 12018,80; *4* — брекчия, обр. 12034,34

(спектры *2* и *1*, спектры *3* и *5*, рис. 1). Спектр диффузного отражения реголита из Моря Изобилия (спектр *4*, рис. 1) по интегральному коэффициенту отражения занимает промежуточное положение между спектрами реголита из Моря Спокойствия и Океана Бурь. Он имеет наименее ярко выраженную структуру, приближаясь по характеру к спектру реголита из поверхностного слоя Моря Спокойствия.

Полученные нами экспериментальные данные находятся в хорошем согласии с данными по измерению спектров диффузного отражения других образцов реголита [3—7]. Численное значение зарегистрированного альбедо для образцов из Моря Изобилия несколько выше, чем альбедо Луны в целом. Однако телескопические данные, полученные для области Моря Изобилия, практически совпадают с данными прямых измерений.

Для более подробного анализа спектров диффузного отражения реголита из разных районов Луны были зарегистрированы спектры четырех шлифов образцов лунных пород, доставленных «Аполлоном-11» (10047,25 и 10048,53) и «Аполлоном-12» (12034,34 и 12018,80). Спектры регистрировались в тех же условиях, что и спектры реголита.

Наблюдается достаточное сходство общего характера спектров исследованных образцов реголита и шлифов (рис. 2): увеличение интенсивности отраженного света с ростом длины волны и присутствие полосы поглощения в области около 1 *мкм*. Однако интенсивность спектров всех шлифов значительно выше, полоса поглощения двухвалентного железа выражена более четко, а различие между образцами шлифов из разных районов Луны по спектрам меньше, чем между образцами реголита. Так, спектры диффузного отражения шлифов 10048,53, 10047,25 и 12018,80 сходны друг с другом, особенно в области 0,8—1,8 *мкм*, а

Page from the book "Lunar soil from the Sea of Abundance"

Taking one of these figures, we outlined with two lines a portion of the visible range, from 400 to 700 nm (in the next figure, these are two vertical blue lines).

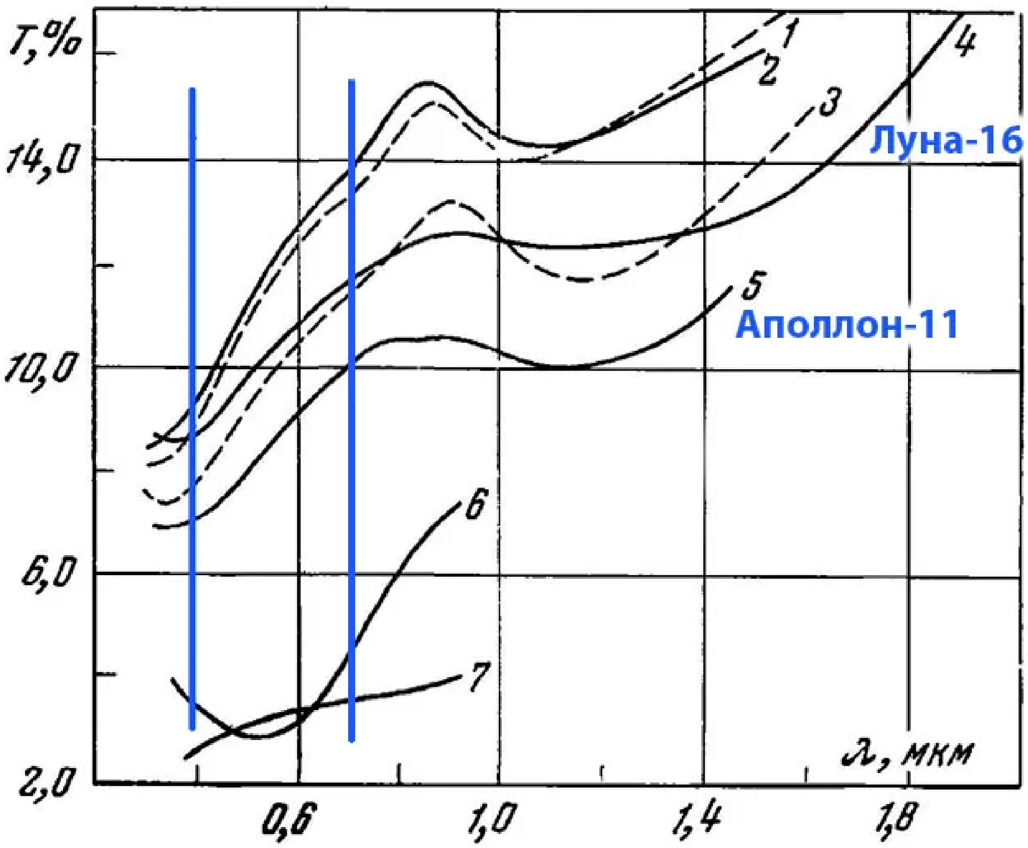


Рис. 1. **Спектры диффузного отражения реголита из различных районов Луны**

1 — обр. 12028,229; *2* — обр. 12028,233; *3* — обр. 10005,35; *4* — обр. Л-16-А; *5* — обр. 10005,34-5; *6* — спектр зеркального отражения обр. Л-16-А; угол падения света 60°; коэффициент отражения в произвольных единицах; *7* — приведенный спектр диффузного отражения обр. Л-16-А; коэффициент отражения при 0,5 *мкм* равен коэффициенту зеркального отражения

Diffuse reflection spectra of regolith from different regions of the Moon

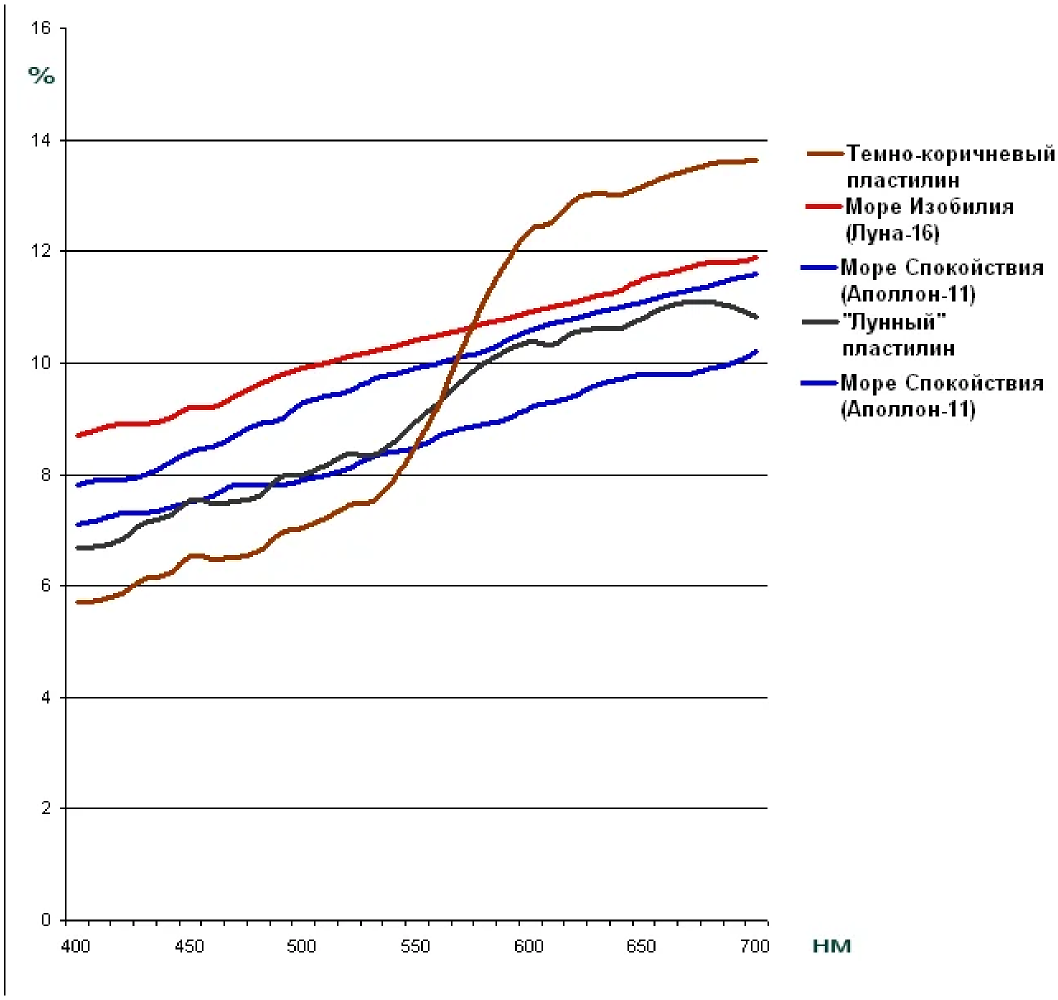
In the visible range, the spectral reflection curve of the lunar soil rises almost linearly upward. In the blue zone of the spectrum, the reflection coefficient is lower, and in the red, it is higher, which clearly indicates that the Moon's soil is not light gray, but dark, with an excess of red, i.e. brown. For gray surfaces, the curve should look like a horizontal line, but we don't see such lines.

Since in different regions of the Moon the soil is not the same in its spectral characteristics, for comparison we took not one, but three curves. One of the curves corresponded to the graph of the spectral reflection of the Sea of Abundance soil (the soil was delivered to the Earth by the Luna-16 spacecraft in September 1970), the other two reflectance curves belong to the soil of the Sea of Tranquility, where, according to legend, Apollo 11 landed.

We transferred these lines to the Exel program, and then from a set of colored plasticine we tried to find a sample close in reflection characteristics to the lunar soil. We started with a dark brown piece.

Colored plasticine. There is a large gray field under the plasticine box with a reflectivity of 18%.

It turned out that the integral reflection coefficient of dark brown plasticine is the same as that of the soil of the lunar seas. In other words, the surface of the moon is about as dark as this dark brown plasticine. But the color of the plasticine turned out to be more saturated than the color of the lunar surface. In the blue zone, plasticine reflected less light than the lunar soil, and in the red zone, more. By adding a small amount of blue plasticine to the brown piece, we reduced the saturation of the color (increased the reflectivity in the blue-green zone). And by adding blotches of black plasticine, the overall reflection coefficient was reduced. After carefully rolling the clay to a homogeneous mass and measuring on a spectrophotometer, we obtained almost the same spectral reflectance curve as in the samples of lunar soil from the Sea of Tranquility.



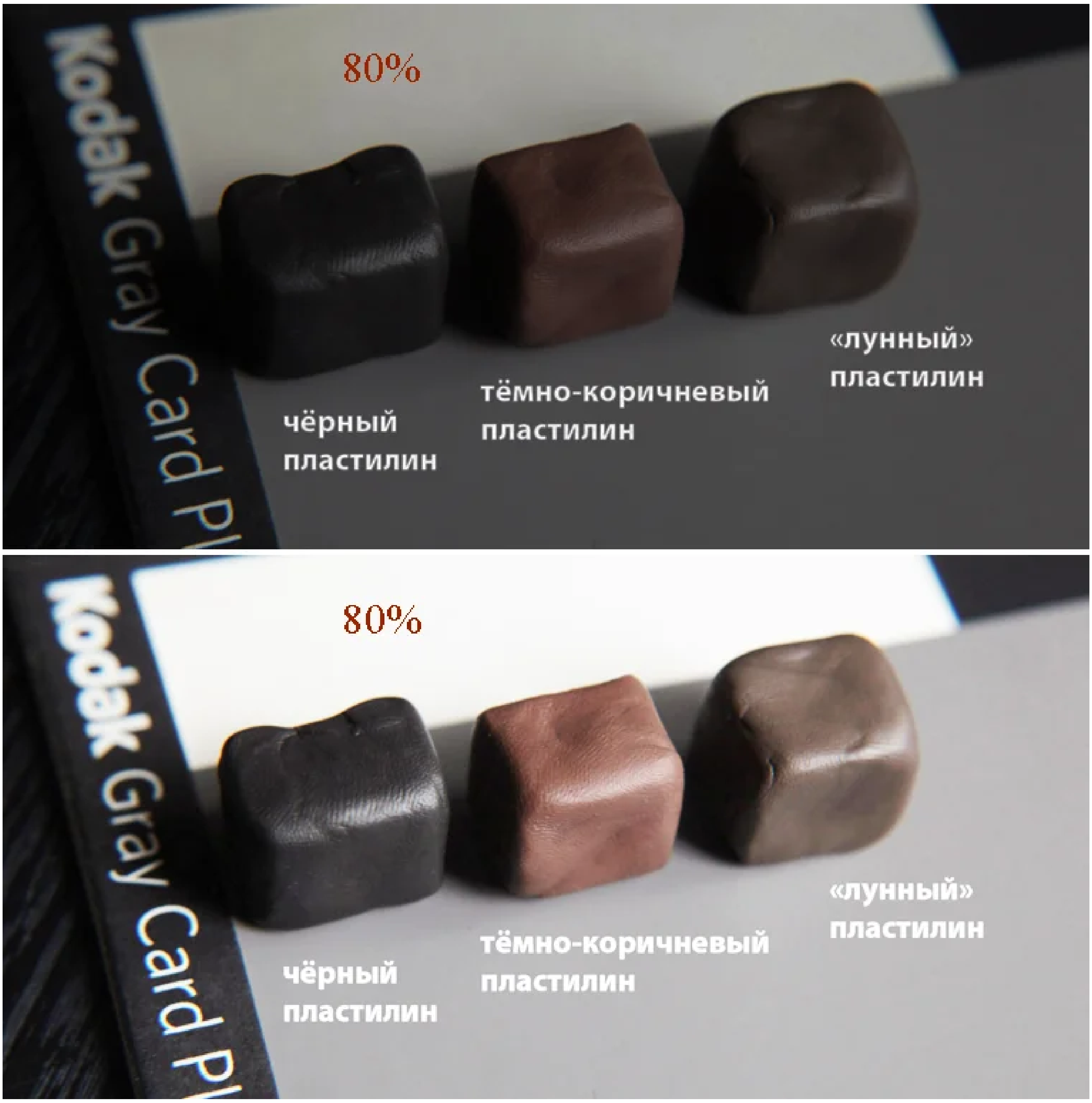
Comparison of the spectral reflection curves of dark brown plasticine with the reflection curves of the lunar soil.

From this plasticine, similar in color to the lunar soil, we molded a cube and photographed it together with the Kodak standard gray scale, not forgetting to put a cube of black plasticine and the original dark brown next to it. This is the color of the lunar seas - as on the cube on the right. This is what the Sea of Tranquility should look like, where, according to legend, Apollo 11 landed.

This is how - the rightmost cube - should look like the lunar soil in the area where, according to legend, the Apollo 11 landing took place.

To get an adequate idea of the color, two main conditions for color correction of the image were fulfilled. First, the plasticine cubes were laid out on a gray scale (Kodak Gray Card) with a reflectivity of 18%. The scale in the picture is **neutral gray** , **there is no color cast on it.**

There is also a white field on the scale, which reflects 80% of the light. Depending on the exposure compensation (during photography), this white field may become grayer or lighter.



Colored cubes were shot with different exposure compensation (exposure).

To remove questions (is the photo too dark or too light?), The brightness of the photo was normalized to the gray field. In s-RGB space, such a **gray field** with an 8-bit color depth should have luminance values of **116-118** . You can check this in Photoshop using the eyedropper.

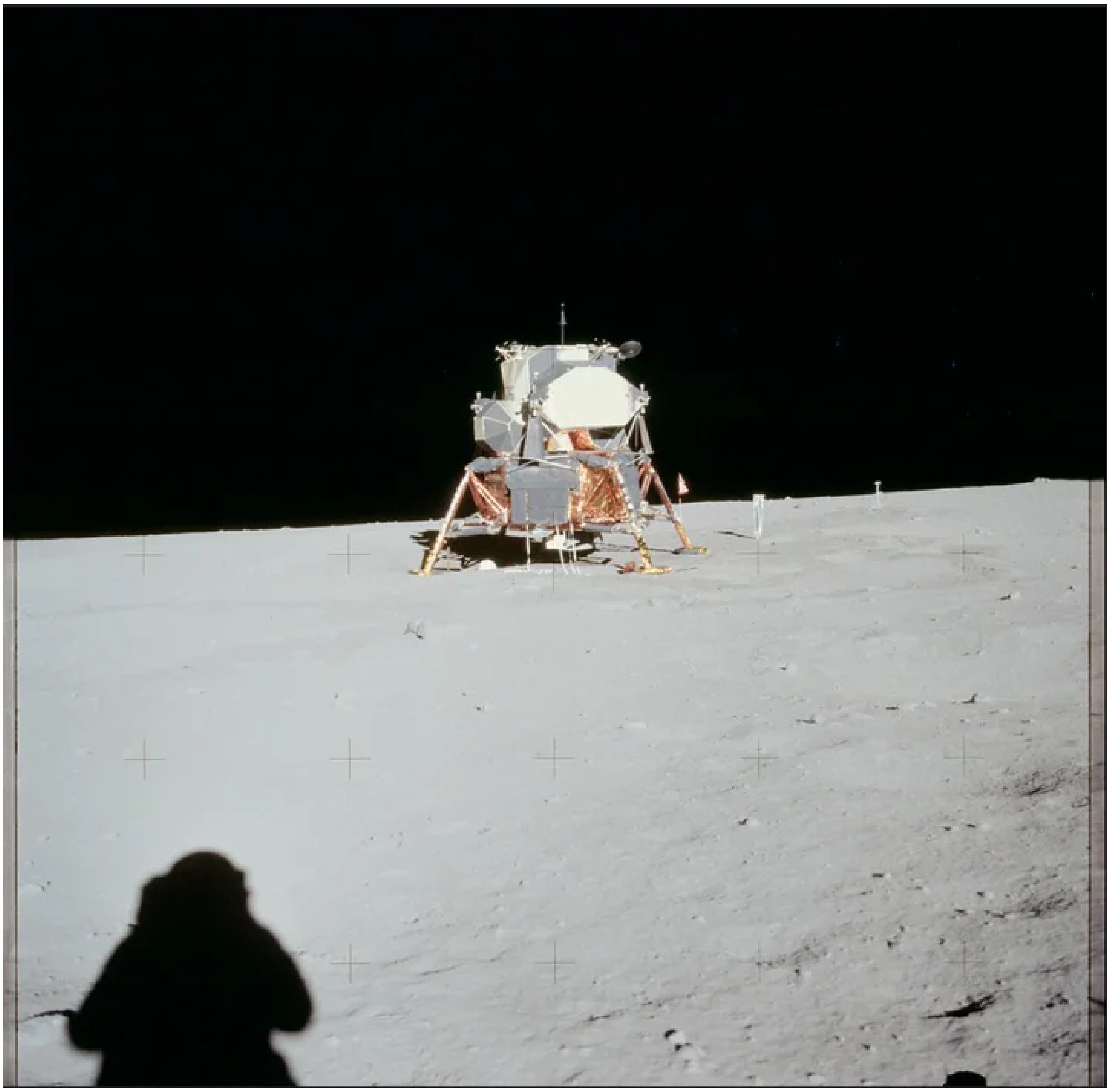
And now, considering various images of the lunar surface, taken from a relatively close distance, it is possible to determine the degree of accuracy in reproducing the color of the lunar surface. For example, in the photograph

"Earth Rising over the Moon", taken by a seemingly automatic probe a year before the Apollo flight, the color of the Moon's surface is reproduced correctly.

Rise of the Earth over the lunar surface.

For some reason, this picture is signed: *View_from_the_Apollo_11_shows_Earth_rising_above_the_moonss_horizon ",* as if this picture was taken by astronauts of the Apollo 11 mission in 1969.

We saw that the astronauts brought pictures with a different color of the lunar regolith (lunar sand):



AS11-40-5962 snapshot from the Apollo 11 mission

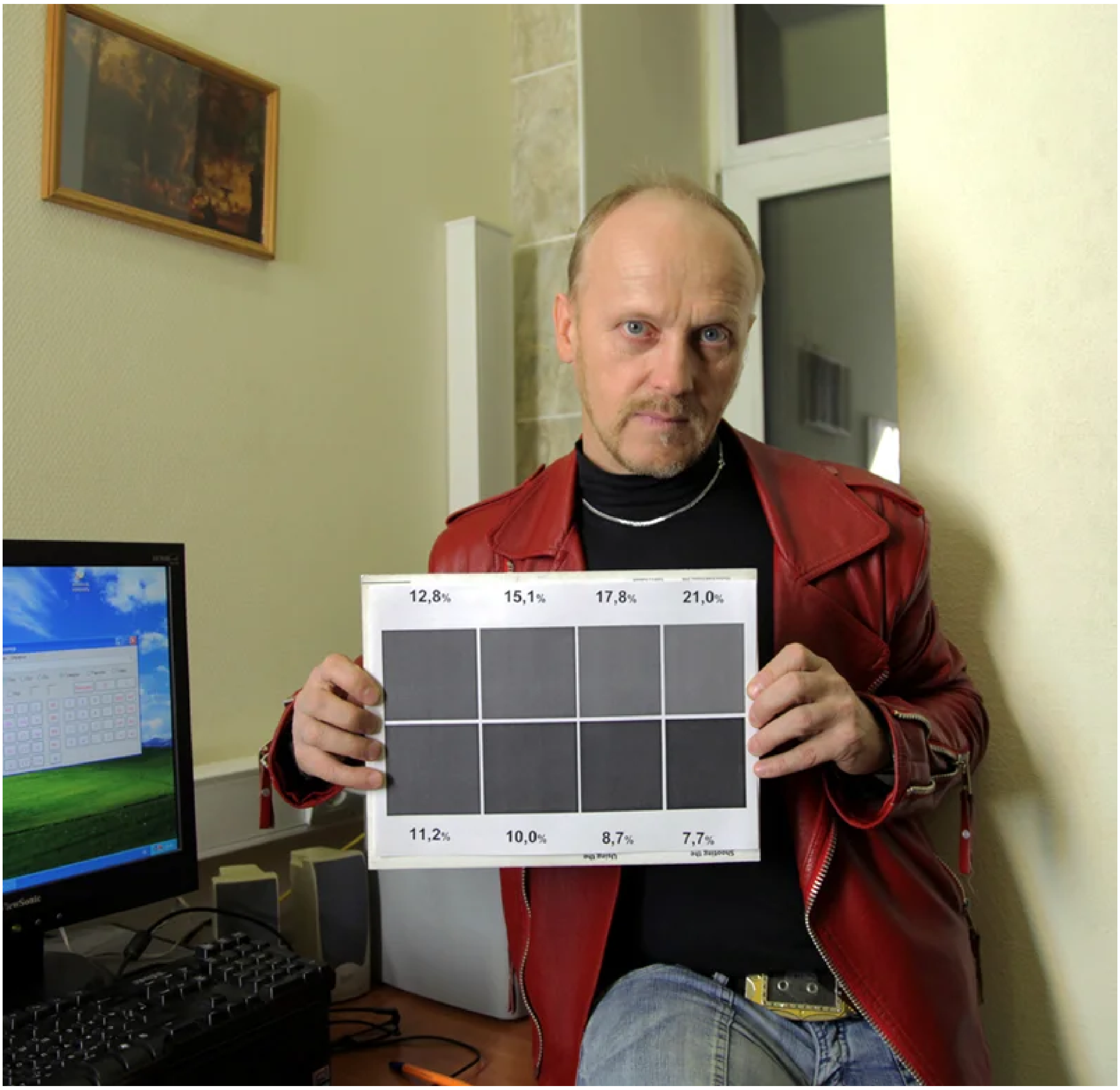
Or here's another picture - Charles Peter Konrad (Apollo 12) examines the "moon" stones he brought. For some reason they are completely gray.

The moonstones delivered by Apollo 12 are completely gray.

You do not have a spectrophotometer, but nevertheless, you can determine for yourself what color of the surface should be in the Sea of Tranquility, which the Apollo 11 allegedly visited. To do this, you need Photoshop and a minute of patience.

You know that the reference gray field in an 8-bit image should have a luminance value of 116. The gray field has a reflectance of 18%. And the lunar soil reflects 7-8%. What will be its brightness in a digital photograph? What will Photoshop show?

Here's a hint for that. I photographed 8 gray fields with a digital camera, and put the reflection coefficient for each field. You do not need to do any mathematical calculations, you do not need to transfer the reflection coefficients to the luminance transmission curve of the digital matrix. You just need to bring the "eyedropper" in Photoshop to one or another field.



The image is normalized to an 18% gray field.

Based on the measurements of the gray squares, we can tell how objects with one or another reflection coefficient will look in an 8-bit photograph. The left column is the reflection coefficient during shooting, on the right is the brightness of the object in a graphics editor on a computer (in Photoshop). The brightness value "0" in Photoshop corresponds to a black tone, "255" - a completely white field.

Bottom 4 squares:

field 11.2% - 92,

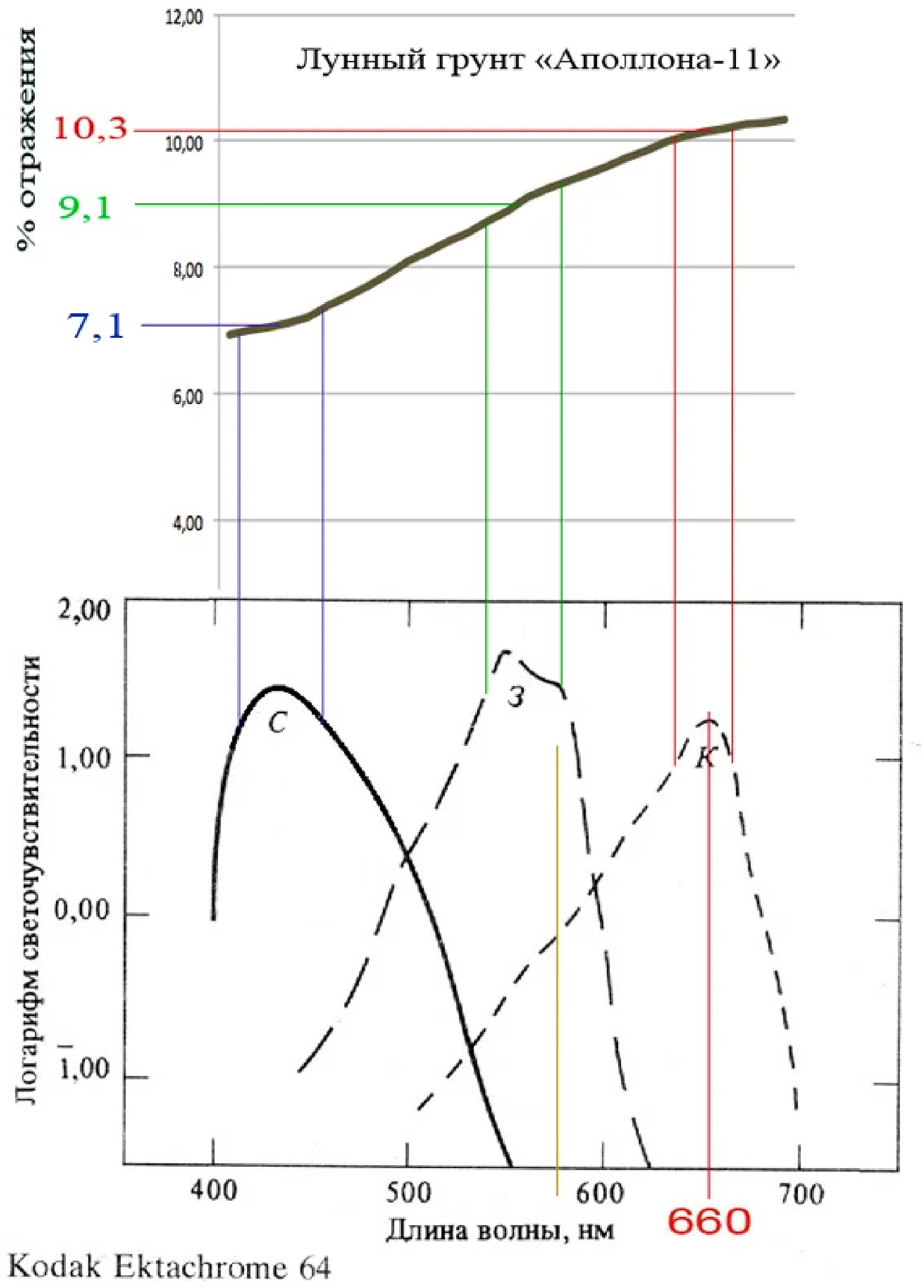
field 10% - 82,

field 8.7% - 70,

field 7.7% - 60

So NASA reports that the images on the Moon were taken with Ektachrom reversible color film. We know the spectral sensitivity of three layers of Ektachrom-64 reversible color film. We also know the spectral characteristic of the regolith reflection from the Sea of Tranquility, where, according to legend, Apollo 11 landed.

We combine these two graphs. Film sensitivity maxima: 410-450 nm in the blue zone, 540-480 nm in the green zone and 640-660 nm in the red zone. (A 2-fold decrease in sensitivity is taken as the boundary of the zone - this is 0.3 on the vertical logarithmic scale.)



Sections of the spectrum in which the lunar soil is seen by the Ektachrom film.

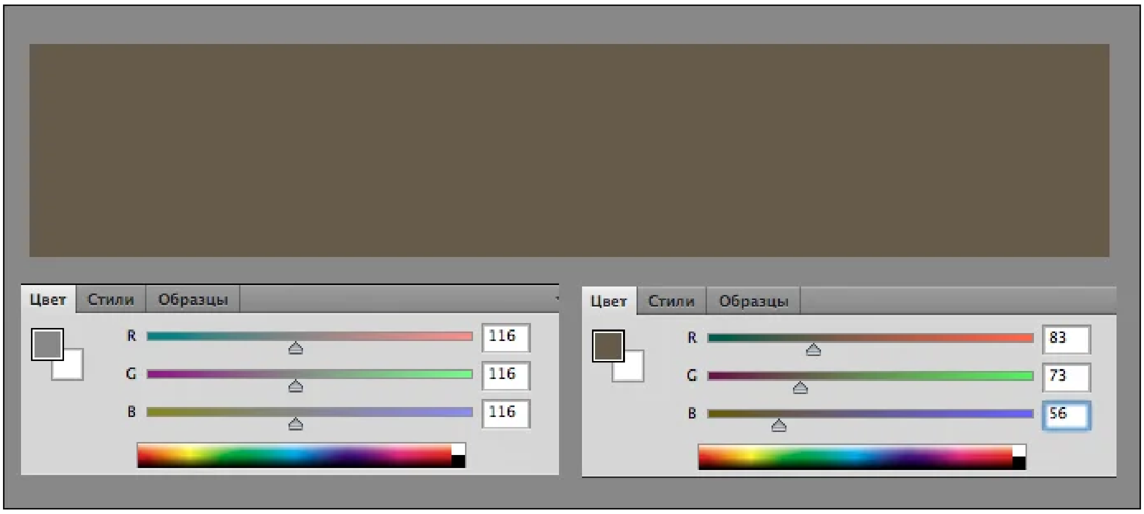
The Ektachrom film will perceive the lunar soil as if it reflected 7.1% in the blue zone, 9.1% in the green zone and 10.3% in the red zone.

The value of 7.1% corresponds to the gradation of brightness "56" in Photoshop. The leash on the blue scale (B) is assigned to this value.

9.1% is the brightness "73" in the green, leash (G).

10.3% in the red zone corresponds to a brightness value of "83".

Thus, the "color" of the lunar surface is obtained, this is exactly what it should be in the photographs in the Apollo 11 mission - brown:

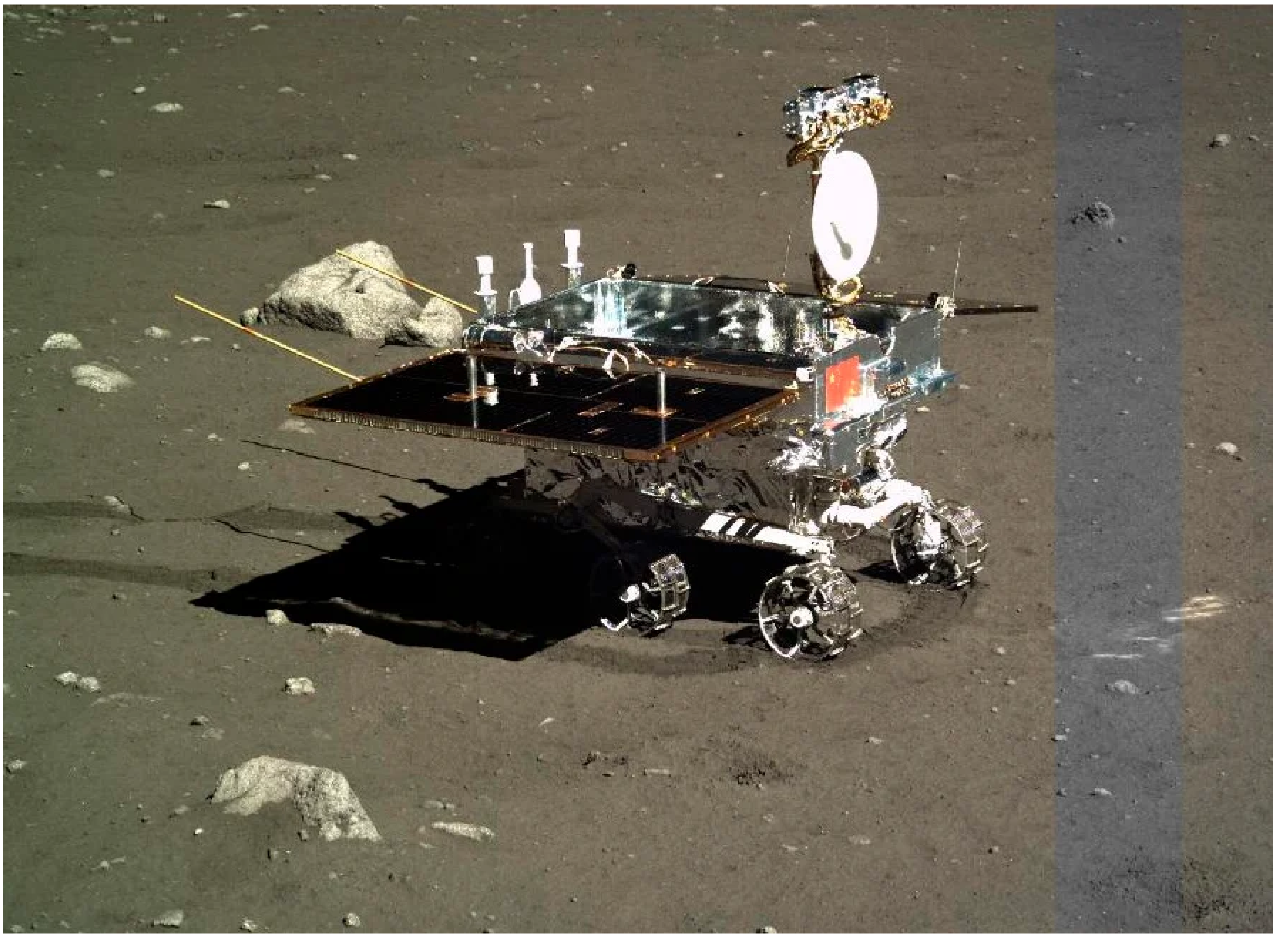


Gray background (116 - 116 - 116, R - G - B), which shows a rectangle with the color of the lunar surface (83 - 73 - 56, R - G - B).

But in the photographs not only of Apollo 11, but also in other expeditions, in the frames where there is a color target with a set of gray and colored fields, the lunar soil looks completely gray. Of course, this is not the Moon. This is a pavilion. And the color of the lunar soil was chosen incorrectly.

Stills from the Apollo 17 mission (AS17-145-22157). On the right in the frame - a color target with colored and gray fields to assess the correctness of color correction.

But in the Chinese photographs, the color of the lunar soil is conveyed much more accurately. So that you can understand how this color differs from gray, we desaturate the vertical stripe on the right side of the image.

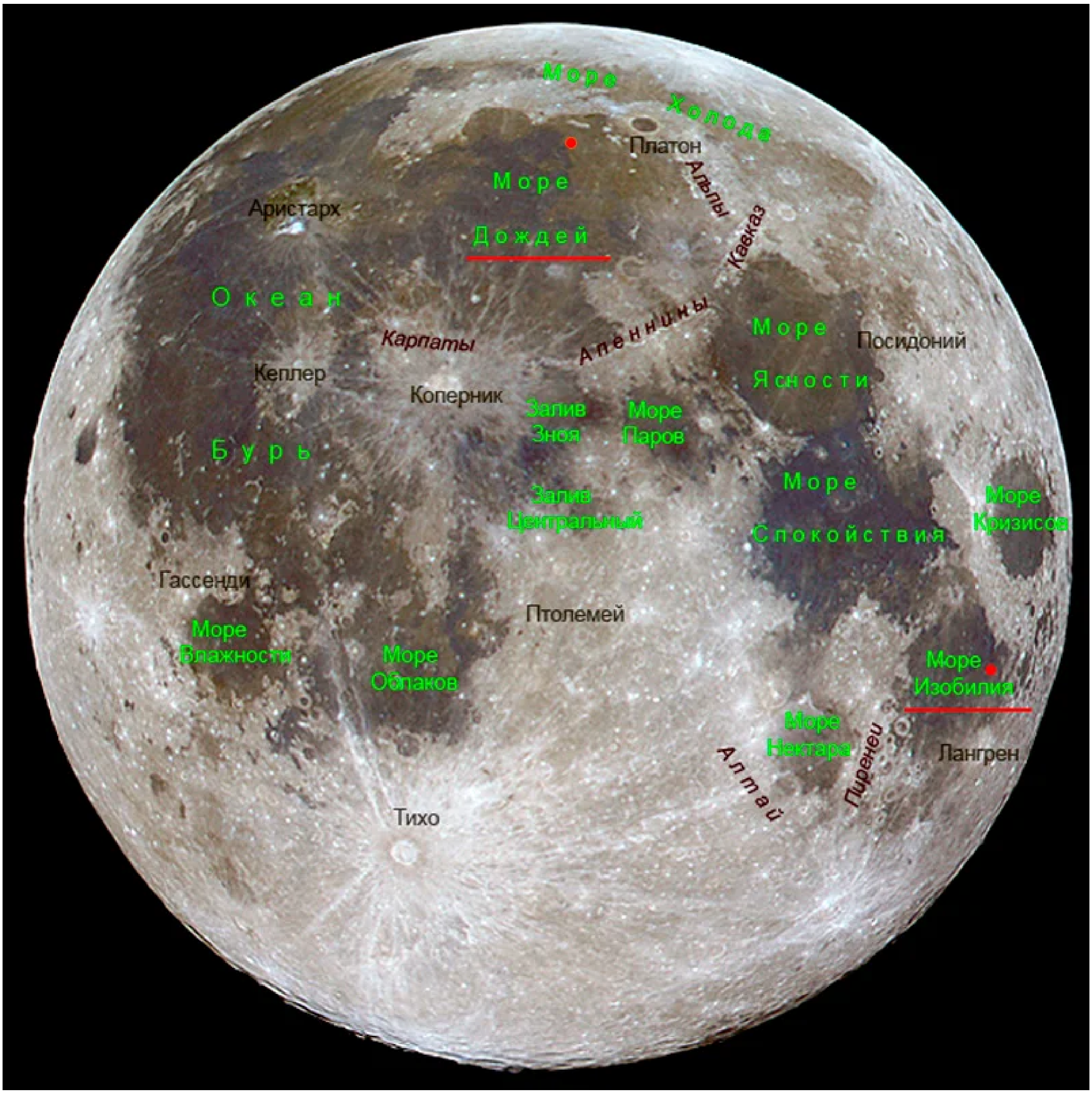


Chinese lunar rover on the moon. The vertical stripe on the right has been specially discolored by us.

Since the spectral reflection curves of the "Chinese" soil can be found on the Internet, we used these curves to select an object similar in color to the regolith in this part of the Moon. The closest color was found for the leather hat.

The color of the brown leather hat was found to be close to the color of the lunar soil at the landing site of the Chinese lunar rover.

The lunar soil in the Sea of Rains, at the landing site of the Chinese lunar rover, visually resembles the color of a dark brown hat. It turned out to be noticeably darker than the area of the Sea of Abundance, where Luna 16 landed (USSR) in September 1970.



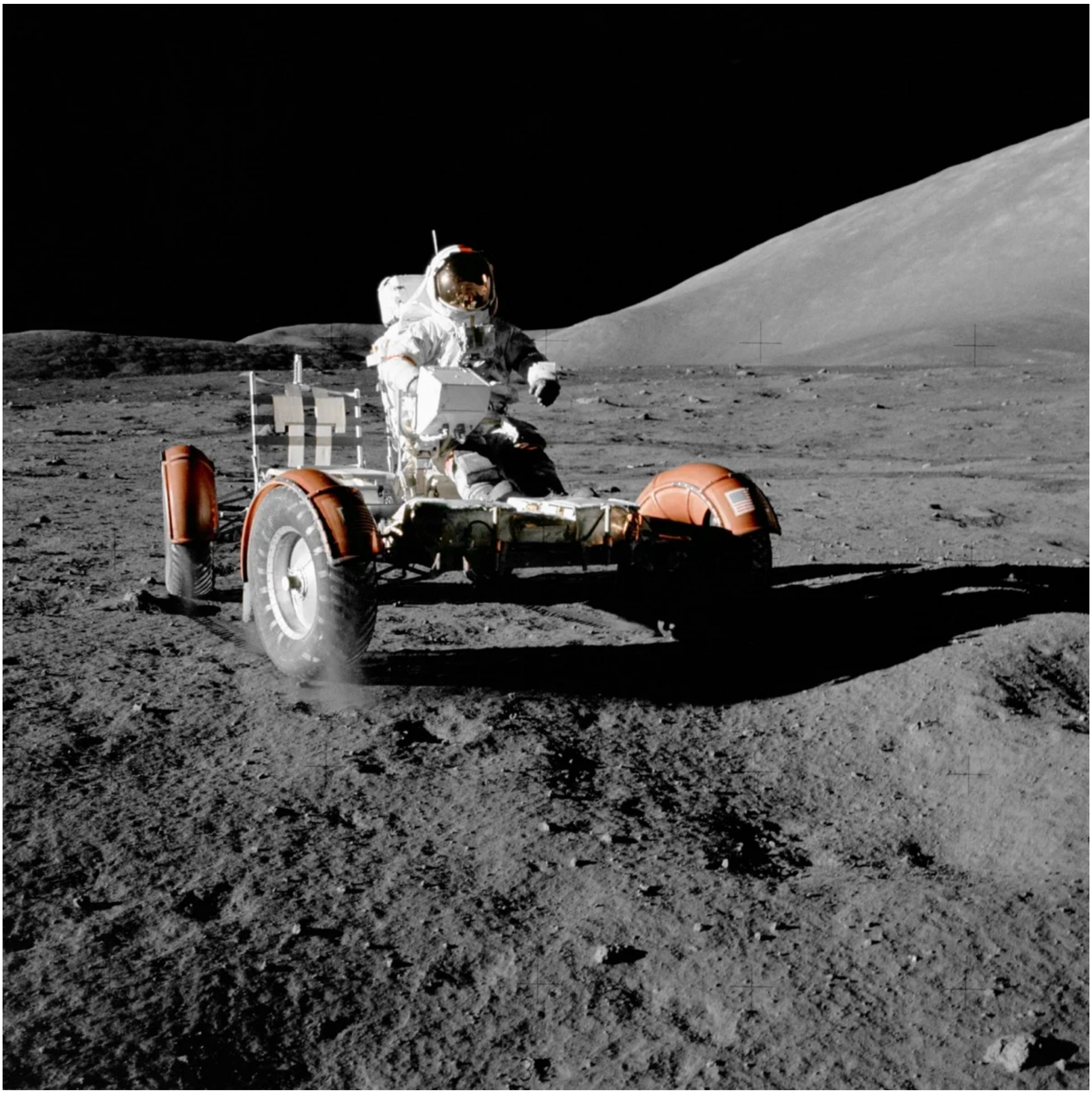
Lunar seas. Red dots mark the landing sites of the Yu-Tu lunar rover (China) in the Sea of Rains and the AMS Luna-16 (USSR) in the Sea of Plenty.

So.

Using the objective color characteristic - the spectral reflection curve of the lunar soil of the Sea of Tranquility, where, according to legend, Apollo 11 landed, we selected an object (plasticine cube) on the spectrophotometer that visually resembles the color of the lunar regolith. The color turned out to be dark brown.

Using the zonal reflections in the blue, green and red zones, we recreated this color in a graphics editor (in Photoshop). It differs markedly from gray.

The fact that the color of the lunar soil in the vast majority of American images from the Apollo missions (1969-72) looks completely gray (in the presence of colored objects in the frame) indicates that these images were not taken on the Moon.



A lunar shot from the Apollo 17 mission (1972) with completely gray sand.

*

Cameraman L. Konovalov was with you.

Until next time!